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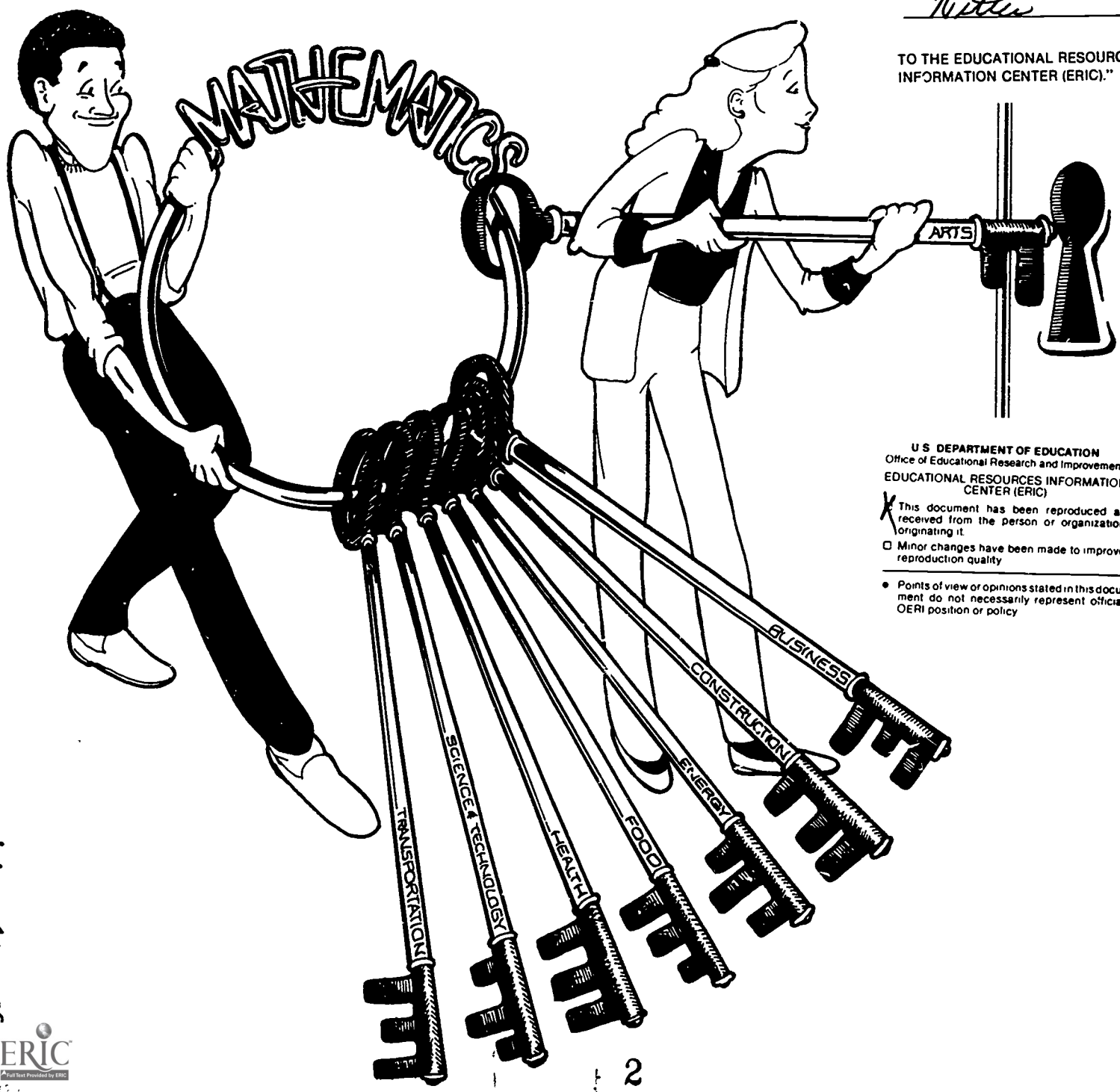
ABSTRACT

The materials from the Mathematics at Work in Society were designed to increase awareness of the connection between mathematics and careers for students of grade 8 or more. This book is designed so that it can be used in a variety of ways by students, teachers, and counselors. The information is on many different careers and the way in which mathematics is used in these careers. There are eight career areas featured in this book. Each one describes some professions and gives some examples of math at work in this career area and activities related to the career area. Career areas included are: (1) fine arts; (2) business; (3) construction; (4) energy; (5) food; (6) health; (7) science and technology; and (8) transportation. Sections are also included on statistics and computer science. (RH)

MATHEMATICS AT WORK IN SOCIETY:

opening career doors



OPENING CAREER DOORS

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The Mathematics at Work in Society (MAWIS) project includes both this project book and a set of four television video tape cassettes entitled: "An Actuary - What's That?", "Mathematics in Space", "Mathematics: The Language of Research", "Mathematics: Where Will I Ever Use It?". These materials have been designed to increase awareness of the connection between mathematics and careers for students of grades 8 and above.

For more information about these materials, write to:

The Mathematical Association of America
1529 Eighteenth Street, N. W.
Washington, D. C. 20036

Any opinions, findings, conclusions or recommendations expressed herein are those of the author and do not necessarily reflect the views of the National Science Foundation.

contents

How to Use This Book

This book is designed so that it can be used in a variety of ways by students, teachers, and counselors. It can be used with or without the video tapes of the Mathematics at Work in Society (MAWIS) program.

Primarily, Opening Career Doors features many different careers, general information about these careers, and the way in which mathematics is used in these careers.

STUDENTS, TEACHERS, and COUNSELORS may use this as a browsing book to obtain general career information or just to learn how mathematics is used in various careers.

STUDENTS and TEACHERS may wish to study this book in detail from page 3 to page 32 or you may wish to read it in any order which is suggested by the interest of the class or the individual. The design will allow it to be used effectively in either fashion.

STUDENTS, don't just read this book, actually do the mathematical exercises as they occur throughout the book. Be sure that you have plenty of paper, a good eraser, a sharp pencil, and no distractions. A hand-held calculator is not a requirement for the exercises, although using one will save time on the computations.

If you are studying this book on your own, there may be times when the mathematical exercises require the use of topics or skills in mathematics which you have not yet learned. In such cases do not be discouraged or frustrated. Use this occasion to ask your teacher for some help.

TEACHERS may use this book:

- as a supplement to whatever text is used in the math classroom;
- as a resource for mathematics exercises which give your students useful career information;
- as a resource for student or teacher presentations of realistic applications of mathematics topics currently being covered in class.

COUNSELORS and TEACHERS may use the book with the video tapes to organize a school-wide career program lasting from one day to one week.

MATHEMATICS: opening career doors

Some of your friends are avoiding high school math classes such as algebra, geometry and trigonometry.

Why do you think they are?

Do you believe avoiding math in high school is the right decision?

Are you aware that by avoiding math in high school you are greatly limiting your earning potential in the future? A fair question you might ask is "what does algebra and trigonometry have to do with my future earnings?" The answer is that mathematics is an important tool of decision-makers and problem-solvers, and these are the people who successfully advance in their chosen careers.

Also most careers require a minimum of two years of high school math, beginning with one year of algebra. If you do not take math in high school, you can count on having fewer career choices later on.

Grouped are some jobs that need at least:

4 years of high school math:

chemist	airline pilot	economist
geologist	veterinarian	astronomer
dentist	computer scientist	physician
	engineer	

Group's 1980 average yearly salary is about $40,000.

3 years of high school math:

teacher	dental hygienist	dietitian
accountant	blueprint drafter	forestry aide
nurse	sociologist	

Group's 1980 average yearly salary is about $20,000.

2 years of high school math:

electrician	social worker	carpenter
police work	medical assistant	machinist

Group's 1980 average yearly salary is about $18,000.

No high school math:

cashier	factory worker
janitor	waiter/waitress

Group's 1980 average yearly salary is about $12,000.

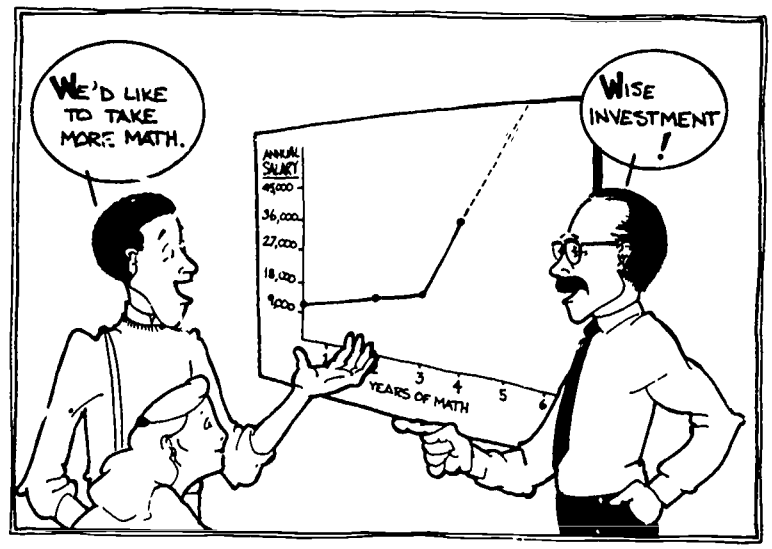
High school math is a wise investment in the future! Two reasons stand out:

- it prepares you for a greater number of career choices,
- on the average, jobs which require more math pay more.

Do this computation using the average yearly salary given on this page:

a) how much more is earned each year at a job needing at least 4 years of math compared to jobs which need 2 years of math?

b) how much more is earned over 30 years of work by taking at least 4 years of math compared to taking just 2 years of math?



Mathematics and your career

When was the last time you thought about what you want to be when you finish school? Pre-school children always talk about their future careers. It's one of their favorite games: "When I grow up I want to be ...?" How did you finish this sentence when you were a child?

Now that you are older, with more responsibilities at home and in school, chances are that you haven't considered a possible future career. This book is designed to help you make some wise decisions related to careers.

"What's the big hurry?" you say, "There's plenty of time to decide on a career." Do you really have plenty of time for a career decision? The answer is yes and no.

Yes, you do have enough time to choose a specific career as you progress through school developing skills, gaining knowledge, and strengthening your own special interests and talents. Your high school years are your "happy days" and they should be enjoyed as such.

But, no, you do not have plenty of time because as a student in high school you are facing and making decisions about the courses you take which will have a long range effect on your future. Your high school courses give you the opportunity to learn to read, to write, and to do math and these are the skills that will make you a success in whatever profession you choose.

This book intends to convince you to take mathematics in high school, especially algebra, geometry, and trigonometry. High school is the best place to take these courses: you have the time for them, you can take them as part of an uninterrupted sequence with students your own age, and you can make use of free public education to take these math courses. Having taken algebra, geometry, and trigonometry you will find that when a career opportunity comes along which you really want you are ready for it. Take math and be ready.

There are eight career areas featured in this book. Each one describes some professions and gives some examples of math at work in this area. Explore these areas in any order that you wish. When you select an area to explore in detail, play the game "what would it be like if I were a . . .?" Imagine it! And if you continue to study math through high school you can make it happen.

FINE ARTS

Which of the fine arts do you enjoy: music, ballet, painting, literature? What special artistic talents do you have: can you draw well, do you have a good sense of rhythm, a good ear for harmony, an eye for beauty? Even if you lack special artistic talents, fine arts may offer you an exciting career. Combining a sensitive appreciation of the arts with mathematics as well as your other high school courses will give you the learning on which to build a successful career in the fine arts.

Music

Everyone enjoys music. But our tastes in music vary from classical to jazz to pop to hard rock. What types of music are your favorites?

Do you know that mathematics and music are related? A Greek mathematician named Pythagoras made this discovery over 2500 years of ago. He discovered the natural harmony of a plucked string of length L with a string of length 1/2 L. This ratio of 2 to 1 is the ratio of a tone to a tone one octave higher. (Octave is the name given to this interval since it is divided into the eight notes of the musical scale.) For example, the middle C string on a piano vibrates 256 times per second, while the note one octave above C on a piano vibrates 512 times per second. The last note on the right of a piano is also a C note, but it is 4 octaves above the middle C. How many times does its string vibrate per second?

Whenever people think of careers in music they usually think of the performing careers: MUSICIAN, COMPOSER, and CONDUCTOR. These are important careers which require much dedication to practice and study. Mathematics is helpful in understanding the theory of music. There are many more careers in music for those who enjoy music: TUNER, MUSIC TECHNICIAN, INSTRUMENT REPAIRMAN, INSTRUMENT CRAFTSMAN, MUSIC LIBRARIAN, BOOKING AGENT, MUSIC SHOP OWNER, and MUSIC CRITIC are just a few. These professions require at least 2 years of high school math, including algebra. Careers requiring a high degree of technical skill such as a tuner or instrument craftsman require even more than 2 years of math.

To build a piano or harpsichord a pianomaker must be knowledgeable with the mathematics of tones. The piano has more than 7 complete octaves, so if the key of C on the right hand end has a string of length 2 inches for its tone, then the length of the string for the lowest C must be 256 inches, more than 21 feet long. (Compute the length of the middle C string.) The pianomaker uses mathematical formulas which explain how to reduce the length of the string yet keep the same tone by adjusting the tension and weight of the string. Check the strings on a guitar. You tune a guitar by adjusting the tension.

This is just one example of the many ways math is at work in music.

Interior Design

INTERIOR DESIGNERS use their skill and training to make indoor areas more useful and attractive. They must have a good grasp of color, principles of design, and geometry, particularly space and symmetry. But is this all? Successful interior designers also need algebra. Surprised!

Customers are always interested in cost. Often the interior designer must present recommendations that are restricted to a budgeted amount.

Suppose a customer wishes to have two walls of a room wallpapered and is willing to spend up to $350 for the wallpaper. One wall is 240 cm high by 378 cm wide, while the other wall has dimensions which are given in the drawing below.

A roll of wallpaper is 52 cm wide by 640 cm long (the pattern repeats every 55 cm). How many rolls of wallpaper are needed for this job and how much per roll can the interior designer spend? Use your math to solve this problem.

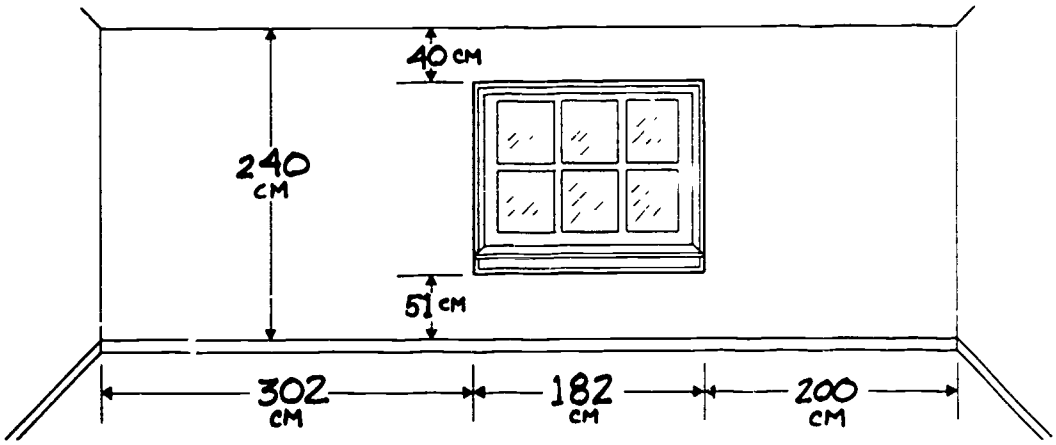
Interior designers, especially those who work on public buildings such as schools, office buildings, or hospitals, must know building materials, building construction, and how to read blueprints. Mathematics, particularly algebra and trigonometry, provides a basic requirement for the mastery of such skills.

Photography

Photography is a popular hobby for many and it is becoming accepted today more than ever before as an art form. Is photography your hobby? It can lead to an exciting career.

The professional photographer must be well trained in math, at least 4 years, chemistry, and physics in order to understand the use of various lenses, films, light sources, and the development process to achieve desired results. Artistic results in photography very seldom occur by accident.

Photographers whether they are PHOTO-JOURNALISTS, PORTRAIT PHOTOGRAPHERS, ADVERTISING PHOTOGRAPHERS, FILM MAKERS, or TV CAMERAMEN are the visible careers in photography. There are other, behind the scenes, careers in photography: DARK-ROOM TECHNICIANS who develop and print film; COLOR-LAB TECHNICIANS who specialize in processing color film; CHEMICAL MIXERS who measure and mix chemicals to make up developing solutions; and PHOTOGRAPH RETOUCHERS.



for more information, write to:

- National Association of Schools of Music, 11250 Roger Bacon Dr., Reston, VA 22090
- American Society of Interior Design, 730 Fifth Avenue, New York, NY 10019
- Professional Photographers of America, Inc., 1090 Executive Way, Des Plaines, IL 60018

mathematics at work in FINE ARTS

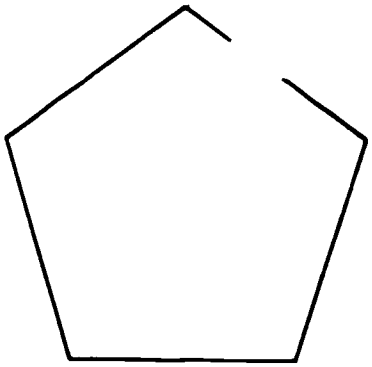
One example of mathematics at work in fine arts is the number $\frac{1+\sqrt{5}}{2}$. The early Greek artists called this number the golden ratio. A rectangle whose sides are ℓ by w is called a golden rectangle if the ratio

$$\ell \div w = \frac{1+\sqrt{5}}{2}.$$

Let's explore the golden ratio.

1. Use a calculator to compute $\frac{1+\sqrt{5}}{2}$ to at least 6 decimal places.

2. Draw a line between every pair of non-adjacent vertices of the regular pentagon to the right. Carefully measure one of these lines and divide its length by the length of one of the sides. Compare this answer to problem 1. (Notice the pattern inside the pentagon. This star is called a pentagram.)

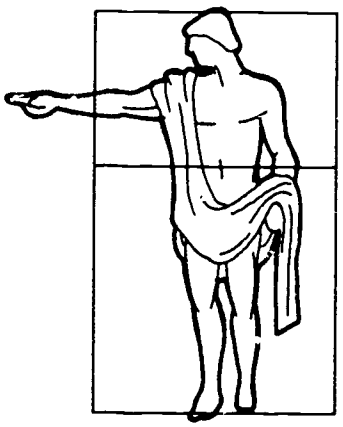


3. The Greeks believed a golden rectangle to be the most pleasing rectangle artistically. Which of these rectangles do you find most pleasing?

Measure them to find which one is a golden rectangle.

4. A PACKAGE DESIGNER combines art with other skills to package an item in an appealing way to consumers. Check the boxes, especially cereal boxes, in the supermarket to find how close many are to being golden rectangles? Make a report to the class of your results.

5. Many SCULPTORS believe that the perfect human figure is related to the golden ratio: in the perfect human figure a person's height divided by the length from navel to toe equals $\frac{1+\sqrt{5}}{2}$. The Statue of Apollo was carved according to this rule. How perfect are you? Measure your dimensions to see how close they come to $\frac{1+\sqrt{5}}{2}$. As a class project compare results. Award the boy and girl who come closest to perfection with a sign that reads "I am a perfect $\frac{1+\sqrt{5}}{2}$".



BUSINESS

Business careers are careers that deal directly with money matters and decisions which are related to profits and losses. To make wise decisions it is necessary to have the right information and be certain that the information is accurate. Mathematics is a major tool which business people use to sort through numbers in order to make wise decisions.

Accounting

ACCOUNTANTS play an important role in the operation of any business, large or small. Let's take a simple lemonade stand. What do we need to start this business? Lemons and water, of course. But also cups, pitchers, ice, napkins, straws, and sugar. What do we charge per cup of lemonade? A COST ACCOUNTANT analyzes the business costs considering the available choices: paper or glass cups, paper or cloth napkins, purchase the ice or make your own, buy lemons in large quantity or as business demands.

To answer some of these questions the cost accountant needs the help of a SYSTEMS ANALYST who combines accounting with a knowledge of statistics and computers to analyze future sales and costs. The systems analyst also coordinates the purchases for the lemonade stand.

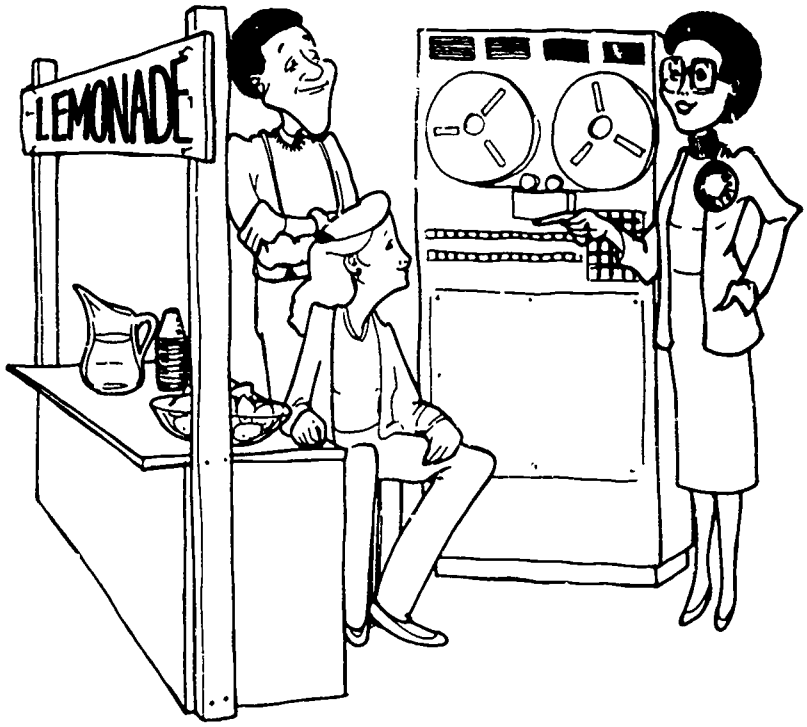
For example, a mathematical and statistical study of data by the systems analyst determines that 50 pounds of lemons are needed for the 3 months of summer. But each order has a shipping charge as well as a storage expense (the lemons must be refrigerated for freshness). The shipping charge is 60 cents per shipment and the storage charge is 10 cents per month for each pound in a shipment. Let s be the number of shipments and y be the number of pounds of lemons per shipment. Then $y = 50 \div s$.

Using math the systems analyst finds the total cost (in cents) of shipping and storing lemons to be given by the formula

$$\text{Cost} = 60 \times s + 10 \times 3 \times y$$

or

$$\text{Cost} = 60 \times s + 30 \times (50 \div s).$$



Take over for the systems analyst; use your math to handle these questions. What is the cost of shipping and storing 1, 2, or 3 shipments of lemons? Try other values for s to find the number of shipments which gives the smallest cost. What is the smallest cost?

From the work of the cost accountant and systems analyst the price of a cup of lemonade is now set. But if we ran our lemonade stand just like many other small businesses we also might need a BUDGET ACCOUNTANT to keep track of the financial condition of our business and a TAX ACCOUNTANT whose specialty is in tax matters to advise us on income tax filing and tax advantages and disadvantages of our business decisions.

As you can see, accountants provide valuable services to business and mathematics is an important tool in their work.

Banking

Money flows in and out of banks. To operate efficiently and accurately, banks must have people who are skilled with handling numbers and computers. High school mathematics helps you to acquire these skills which are so important in banking.

An ACCOUNT CLERK who records financial transactions and a RECONCILEMENT CLERK who checks accounts for accuracy are examples of banking careers which require two years of math. A LOAN OFFICER who handles and evaluates applications for car, home or farm loans and an OPERATIONS OFFICER who plans and coordinates the bank's computer systems are examples of careers which require at least four years of math.

A loan officer uses math to evaluate whether a customer can afford to make the monthly payments for a loan. Suppose a high school student earns $67 per week at a part-time job and wishes to borrow $6000 for a new car. The bank will loan this amount at 15% interest for 36 months. To compute the monthly payment, the loan officer uses the mathematical formula

$$R = \frac{A \times r}{1 - (1 + r)^{-m}}$$

with A = $6000, m = 36, and r = 0.15 ÷ 12. This formula would be difficult to understand if the loan officer did not have a good math background in algebra, logs, and exponents. The monthly payment for the car loan given by the formula is $208. Would you approve this loan? Before you answer consider the other expenses the student will have by owning this car.

Consumerism

CONSUMER is the name given to people who use goods and services to satisfy personal needs. You are a consumer and you will continue to be for the rest of your life. The math that you take in high school will aid you as a consumer.

- Math prevents being overcharged or shortchanged;
- Math balances checkbooks;
- Math discovers errors on credit accounts;
- By calculating the unit price (price of item ÷ quantity) math determines the most economical buy;
- Math helps with do-it-yourself building and repair projects;
- Math helps you to read graphs and to interpret data in newspapers and magazines.

And if you take 4 years of high school math you will have the background to compute interest on savings accounts, to compare home and car financing as well as many other money saving tasks.

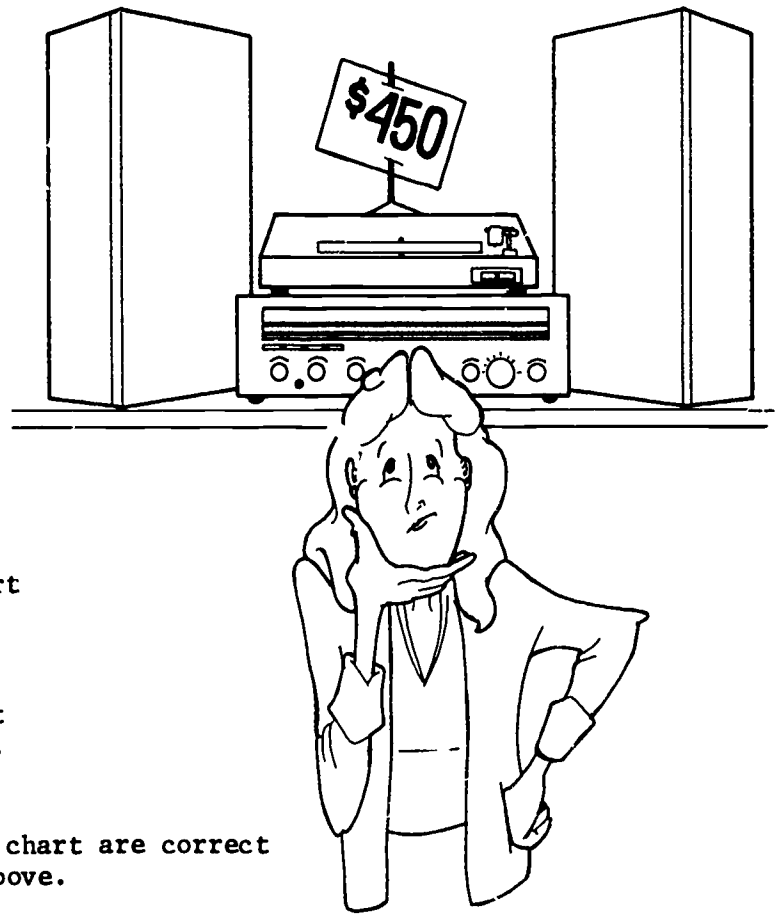
Math is, indeed, a wise investment.

for more information, write to:

- American Institute of Certified Public Accountants, 1211 Avenue of Americans, New York, N. Y. 10036
- American Bankers Assoc., Bank Personnel Division, 1120 Connecticut Ave. N.W., Washington, D. C. 20036
- National Association of Bank Women, Inc., National Office, 111 E. Wacker Dr., Chicago, IL. 60601
- Consumer Information Center, Pueblo, CO 81009.

mathematics at work in BUSINESS

Let's buy a $450 stereo system and charge it on the store's revolving charge account. The store charges 1.5% interest on the amount owed at the start of each month. We agree to pay $15 each month.



The chart below shows the monthly tally for our revolving charge for the first 3 months:

MONTH	BALANCE	INTEREST (1.5%)	UNPAID BALANCE	PAYMENT
1	450.00	6.75	456.75	15
2	441.75	6.62	448.37	15
3	433.87	6.50	439.87	15
4				15
5				15

Here is how each column in the chart is computed:

Interest = Balance × .015
Unpaid balance = Balance + Interest
Balance = Unpaid balance - Payment.

1. Verify that the figures in the chart are correct by using the simple formulas above.

2. Compute the balance, interest and unpaid balance for months 4 and 5.

3. How much money was paid on the stereo in the first 5 months? How much of this amount is for interest?

4. What percent of the first 5 months payments is interest?

Would you like to know how many payments must be made to pay off the stereo? One way to obtain the answer is to continue the chart until the balance is zero. Mathematics, if you have the proper background of courses, provides an easier way. Let A = $450, R = $15, and r = 0.015 in the formula given in the banking section and solve for m. The answer is m = 41 payments.

5. By using the revolving charge account, how much did the stereo cost? How much of this is interest?

How long will it take to save $450 if I put $15 each month into a savings account which gives 6% interest compounded monthly?

Here again a math formula gives us the answer: 28 months. This is more than a full year less than to pay off the stereo by charging it.

This information helps to decide: to save for the stereo or to charge it?

Math helps consumers make decisions.

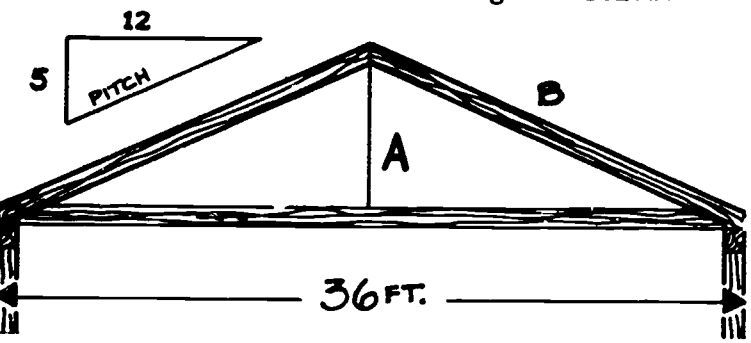
CONSTRUCTION

The construction industry requires people of different levels of training and skill to work together as a team. The most important activities in the construction of a highway, a shopping mall, or a similar large project are measuring, testing materials, and problem-solving. To perform these activities well the construction worker must know mathematics well.

Carpenter

A CARPENTER is an indispensable member of every construction project. Skilled carpenters are needed to cut, shape, and join materials together. There are two types of carpentry work: "rough" and "finish". Most skilled carpenters can do both. FINISH WORK CARPENTERS install molding around floors, doorways, and windows; they build cabinets, bookcases, and install woodpaneling. ROUGHWORK CARPENTERS put up forms for cement and the wood framework in a building.

Let's join a roughwork carpenter on the job to see how mathematics is used. The project is to build the wooden frame for the roof of a house. A side view of the roof is given below.



The pitch is the carpenter's term for the slope of the roof. The diagram shows that the roof rises 5 feet for every 12 feet of horizontal run.

The carpenter needs a hammer and nails to assemble the wooden frame for the roof. But first the carpenter needs mathematics: ratios, similar triangles, and the Pythagorean formula to find the lengths of the wooden beams labeled A and B in the diagram.

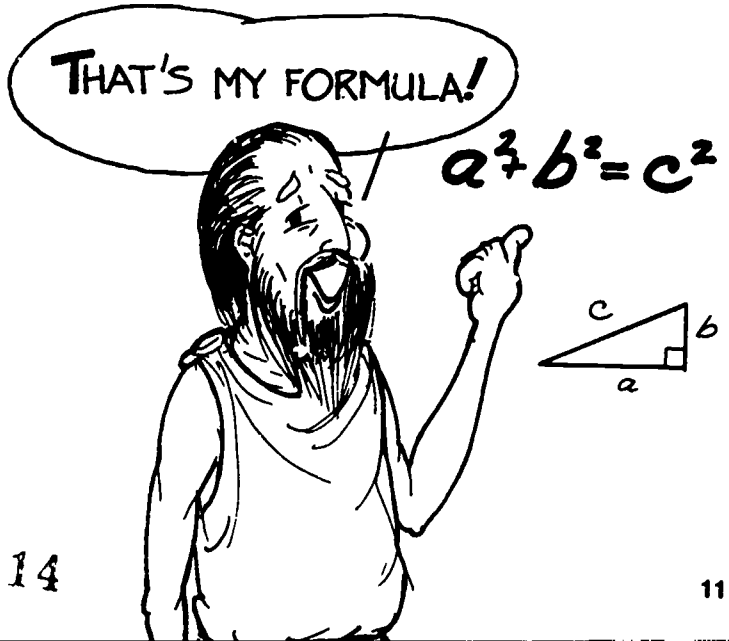
Can you do the math to find the length of A and B?

Construction Electrician

CONSTRUCTION ELECTRICIANS also follow drawings and blueprints to install wiring, switches, and electrical outlets. Training for a construction electrician, a carpenter, as well as other construction trade workers, begins with an apprenticeship program after graduation from high school.

An apprenticeship program is an on-the-job training program in which you learn the trade as an assistant or helper to a skilled trade worker. These programs are usually sponsored by union or contractor associations. They last from 2 to 4 years and they include classroom instruction, as much as 576 classroom hours, on the use of the tools and procedures of the trade.

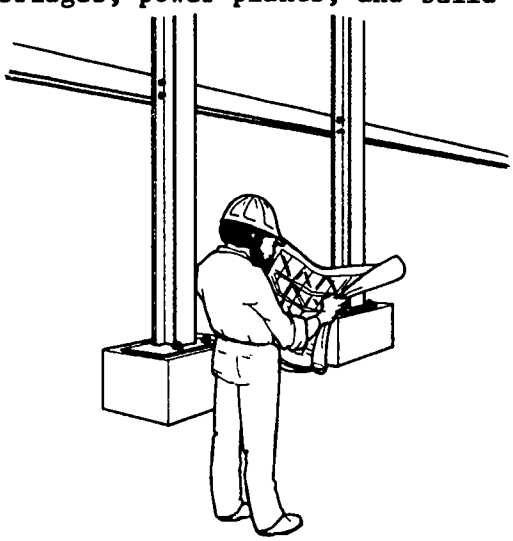
One classroom topic studied in all construction trades is the mathematics needed for drafting, blueprint reading, and laying out construction work. One year of high school algebra gives you the preparation for the mathematics of the construction trade.



Civil Engineer

Have you ever watched a large construction project such as the construction of a highway or a building? If you watch carefully you will notice someone in charge wearing a hardhat. It may be a man or a woman, but whoever it is the individual goes from one part of the construction site to another, usually carrying a rolled up blueprint, taking measurements and comparing them against the blueprint. This is a CIVIL ENGINEER.

Civil engineers design and supervise major construction projects such as roads, bridges, power plants, and buildings.

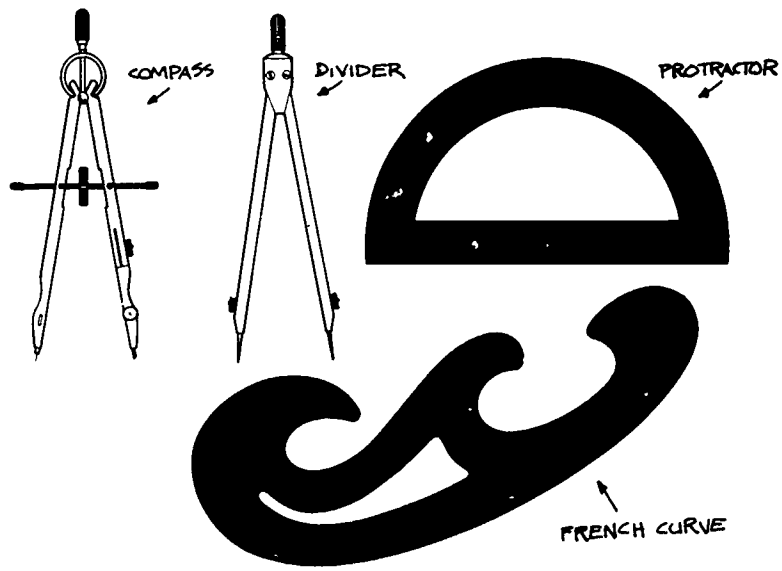


A civil engineer needs very technical and scientific training. The high school curriculum should be selected which gives the best preparation for college-level science and engineering courses. Consequently, to prepare for the college civil engineering program four years of high school math, including two years of algebra, geometry, and trigonometry, is a must.

Drafter

DRAFTERS draw the construction plans which show the exact dimensions of the entire project and each of its parts. These drawings are based on rough sketches, details, and calculations from the architect, the scienctist, and the engineer.

The basic tools of the drafter are the compass, the divider, the protractor, the French curve, triangles, and calculators.



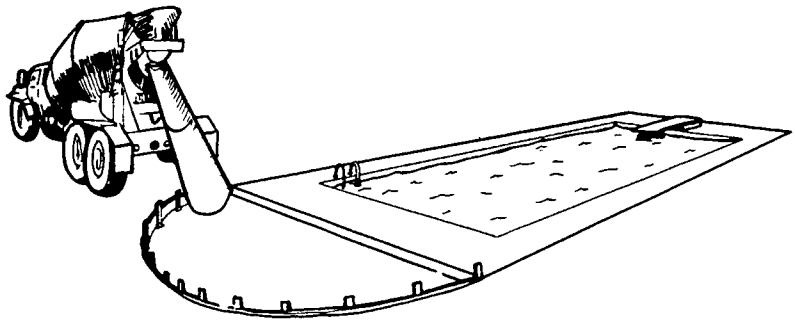
The drafter also needs mathematics to make the drawings accurate, particularly arithmetic, ratios, proportions, geometry, trigonometry, and algebra. The construction plans for a house is an example in which the drafter must reduce the drawing according to a mathematical scale so that it can be drawn on paper. To represent the exact dimensions of each and every detail in such a drawing requires the drafter to have the ability to solve problems involving fractions easily and reliably.

for more information, write to:

- Associated General Contractors of America, 1957 E. Street, N. W., Washington, D. C. 20006
- Accreditation Board for Engineering and Technology, Inc., 345 E. 47th St., New York, N. Y. 10017
- Society of Women Engineers, 345 E. 47th St., New York, N. Y. 10017

mathematics at work in CONSTRUCTION

A CEMENT MASON pours and finishes concrete surfaces. The cement mason is faced with a job to order, pour, and finish the cement for a walkway and patio around a customer's newly built swimming pool. See the drawing of the cement work to be done.



The walkway is 4 ft. wide and borders the perimeter of the pool and the patio is a semi-circle located at one end of the pool. The pool itself has dimensions 16 ft. by 30 ft.

To plan for this job the cement mason must schedule the number of cement trucks to pour the cement. The cement is poured to a depth of 4 in. thick and a fully loaded cement truck carries 7 cubic yards of cement. The cement mason needs mathematics to answer some basic questions:

1. What is the area of the cement work around the pool?

2. How many cubic yards of cement are needed for this job?

3. How many cement trucks should be scheduled for this job?

4. The customer is interested in the cost of the cement. If the price of cement is $42.35 per cubic yard, what is the cost of the cement for this job?

Use your mathematics to answer these questions for the cement mason. The formula for the area of a circle, $A = \pi r^2$ (π approximately equals 3.14), is useful in this problem.

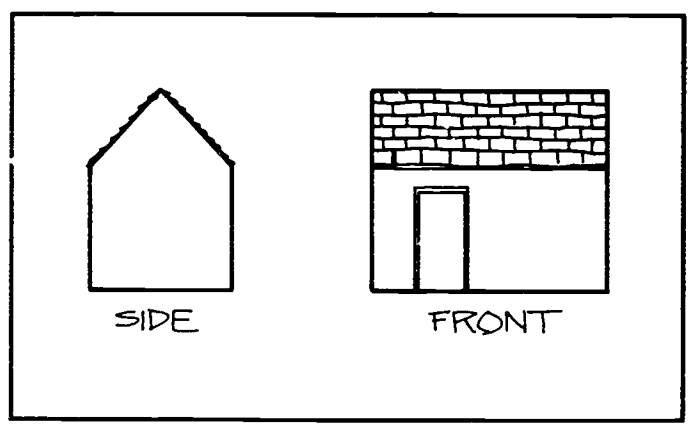
A PLUMBER is also working on the construction of this swimming pool. Using mathematics the plumber determines what supplies to take along before leaving the shop.

The plans for this job call for some straight sections of pipe of various lengths: two pieces 8 3/4 ft. long, six pieces 4 5/8 ft. long, and two pieces 1 3/8 ft. long. The supply room has only 12-foot sections. The plumber has equipment which allows these 12-foot sections to be cut to size at the construction site.

1. What is the smallest number of 12-foot pipe sections which should be taken to the construction site?

2. How should the 12-foot pipe sections be cut in order to have the smallest number of extra pieces (keeping the extra pieces down to a minimum reduces waste and also cost)?

A drafter has drawn a side view and a front view for a storage house which will hold the pool's filtering system:



The scale for these drawings is $\frac{1}{16}$ in. to the foot.

Measure the length, width, and height of the drawings and from these measurements give the actual dimensions of the storage house.

ENERGY

Scientists and engineers have recently been focusing their interest on two "energy sources" which together will increase the energy supply of the United States by 50%. One of the "new" sources is the improvement of techniques of energy generation from the fuels which we currently use. This is the challenge for those in the energy related careers and you can be sure that mathematics training will aid them in meeting this challenge. The other source is the reduction of energy waste in our homes, schools, cars, and factories. This challenge begins with you: look for ways to save energy.

Heating, Cooling, Refrigeration Technician

How much does it cost to run a window air-conditioner? The HEATING, COOLING, and REFRIGERATION TECHNICIAN can answer this question by using his mathematics training.

Let's try an example. Suppose an air-conditioner uses 0.89 kilowatts of electrical power (1 kilowatt = 1000 watts). If it runs for 24 hours, then it uses $0.89 \times 24 = 21.36$ kilowatt-hours, abbreviated kwh, of electricity. If electricity costs \$.06 per kwh, then the cost of running this air-conditioner is $21.36 \times 0.06 =$ \$1.28 per day.

Find the number of watts to run an electrical appliance such as your TV. Every applicance has a label on it which gives this information. Also call your local electric company to check the cost for one kwh of electricity. Use this information to compute the cost of watching TV for a day, a month, a year.

The heating, cooling, and refrigeration technician is also interested in heating and cooling loss, and energy efficiency. The mathematics for these computations requires at least two years of high school algebra and the use of technical handbooks and calculators.

Formal training for a heating, cooling, and refrigeration technician can be obtained at a technical institute, junior or community college, or a local vocation-technical school. A good training program will teach the design, manufacture, and service of heating and cooling equipment.

Geologist

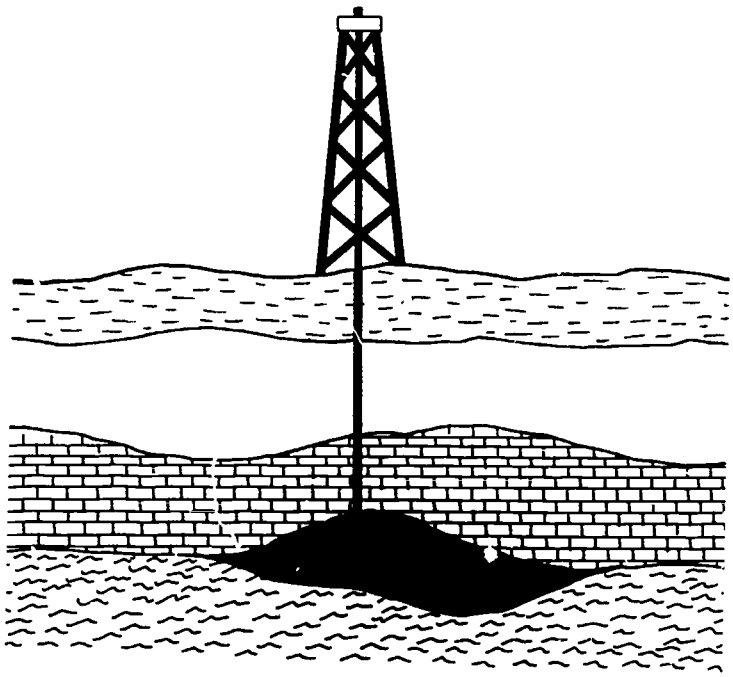
The search for oil, natural gas, and coal, the primary energy fuels, as well as the search for other minerals is the job of the geologist. Much of the work of the GEOLOGIST is done outdoors in rocky terrain taking rock samples with hammers and chisels.

In his work the geologist also uses many complex instruments which require mathematics. To take precise measurements of large rock formations or the width of a canyon the geologist uses trigonometry and a transit, a telescope which measures angles accurately. To measure the strength of the earth's gravity and the intensity of earthquakes the geologist uses a gravity meter and a seismograph. The standard measure of the intensity of earthquakes is the Richter scale, a scale which is based on logarithms - another example where math is needed.

Sometimes a geologist can estimate the amount of oil or natural gas in a rock bed from the rock samples taken. Suppose the samples and tests taken indicate that there is an oil pocket which averages 16 feet thick and covers 20 acres. The rock formation is found by tests to be saturated at the 1% level with crude oil. The formula for the number of barrels of crude oil is

$$\text{BARRELS} = 7758 \times T \times A \times S$$

where T denotes the average thickness in feet of the pocket, A denotes the area in acres of the pocket, and S denotes the saturation of oil in the rock of the pocket (S is expressed in decimal form). Using this information, compute the number of barrels of oil in this pocket. If the price of crude oil is $45 a barrel, is this a million dollar pocket?



Engineer

Fundamental laws of science state that when you convert one form of energy such as coal into another form such as electricity, part of the original energy is lost as a result of friction and other factors in generators and boilers which make the conversion. As much as two-thirds of the energy in fuels is currently lost in generating electricity. This loss is higher than it should be.

Who will play a central role in squeezing a larger percent of energy from the energy fuels? Men and women engineers!

MECHANICAL and ELECTRICAL ENGINEERING are two engineering careers which specialize in the area of efficient energy conversion. Mechanical engineers are concerned with the production, transmission, and use of energy; they search for ways to harness solar and nuclear energy. Electrical engineers design and operate electrical power plants.

If you want to contribute to solving the energy crisis as a mechanical or electrical engineer you must attend college for four years in an engineering program which contains a steady diet of mathematics and science. The time to begin preparation for an engineering career is in high school: take two years of algebra, geometry, trigonometry, and science.

Other kinds of engineers will also be involved with solving the energy crisis. MINING ENGINEERS deal with the problems of finding and extracting minerals; they also design and supervise the construction of mines. PETROLEUM ENGINEERS address the problem of maximum recovery of oil and natural gas with the most economical production methods.

for more information, write to:

- National Society of Professional Engineers, 2029 K St. N.W., Washington, D. C. 20006
- Institute of Electrical and Electronics Engineers, 345 E. 47th St., New York, N. Y. 10017
- American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 345 E. 47th St., New York, N. Y. 10017
- Society of Women Engineers, 345 E. 47th St., New York, N. Y. 10017
- American Geological Institute, 5205 Leesburg Pike, Falls Church, VA 22041

mathematics at work in ENERGY

Let's measure the heat loss through a window.

Heat moves from an area of high temperature to an area of low temperature. For example, if the inside temperature of a building is 70 degrees and the outside temperature is 45 degrees, then the heat of the inside will be transferred to the outside.

For a window the rate of heat loss depends on the area of the window, the thickness of the glass, the difference between the inside and outside temperatures, and the thermal resistance of the glass, each expressed in the appropriate units. The formula for the rate of heat transfer Q is:

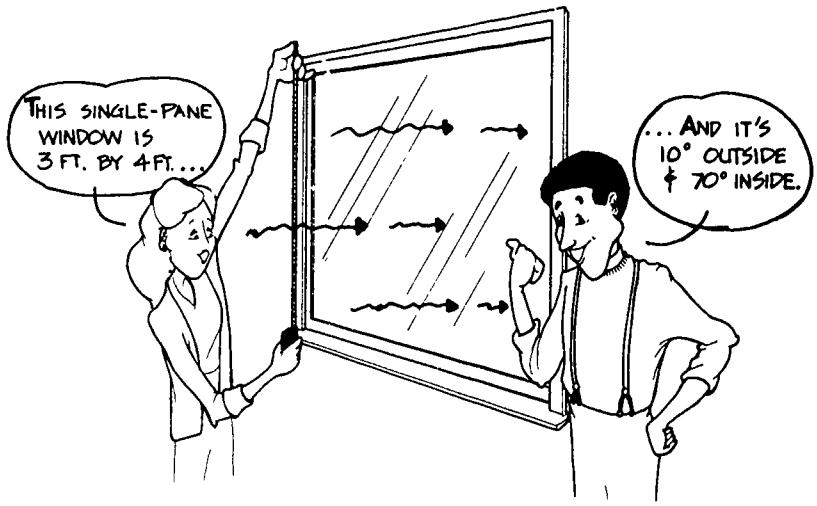
$$Q = \frac{A \times T}{R},$$

where the rate Q is expressed in BTU per hour (BTU stands for British Thermal Unit; one BTU is the amount of heat needed to raise the temperature of one pound of water one degree); A is the area of the glass in square feet, T is the difference in outside and inside temperature in degrees Fahrenheit, and R, the thermal resistance, is the number which measures the material's resistance to the flow of heat through it. The R value for a single-pane window is 0.88, whereas for a double-pane window (window with storm windows) the R value is 1.79.

1. Calculate the rate of heat transfer from a single-pane window, 2 ft. by 2 ft., when the inside temperature is 70 degrees and the outside temperature is 26 degrees.

2. Calculate the rate of heat transfer from a double-pane window, 2 ft. by 2 ft., when the temperatures are the same as in problem 1.

3. What is the rate of heat transfer from a single-pane window 4 ft. by 8 ft., in an air conditioned building when it is cooled to 72 degrees and the outside temperature is 94 degrees?



4. A home has 5 windows 2 1/2 ft. by 4 ft., 4 windows 1 1/2 ft. by 1 1/2 ft., and one window 5 ft. by 4 ft. Calculate the total number of BTU's transferred in one full day for a single-pane and for a double-pane window when the inside temperature is kept at 70 degrees and the average outside temperature is 30 degrees.

5. Suppose the cost for heating is $5 per million BTU's and the cost of cooling is $9 per million BTU's (the actual costs vary throughout the U.S.). How much is saved in one day by using double-pane windows instead of single-pane windows given the data in problem 4? How much is saved in a 30 day month in which the average outdoor temperature is 30 degrees? How much is saved in a 30 day month in which the average outdoor temperature is 90 degrees?

6. Measure the windows in your home or classroom and calculate how much is saved with double-pane windows in one full year? You will need the average temperature for each month for your community. A library or the weather station at a nearby airport are sources for this information.

FOOD

Food is fuel for our bodies. If our bodies receive too little food and not enough nutrients (vitamins and minerals), we do not have the energy to do our best throughout the day. Some people carefully control their diet by counting calories and vitamins. Though it is our own responsibility to see that we eat the proper food, those who work in food related careers provide the food that we eat; farmers, food scientists, and dietitians all find mathematics a very useful tool in their work to supply the world with high quality and nutritious food.

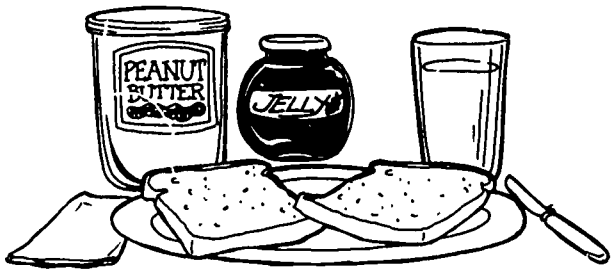
Dietitian

A DIETITIAN is a person with training in food and nutrition who plans diets, supervises meals, and manages food purchasing with a concern for its nutritional value. To become a dietitian it is necessary to attend college and major in food and nutrition. Professional recognition as a dietitian requires on-the-job training from 1 to 2 years after college. Most dietitians work in hospitals, schools, and clinics.

Let's take a look at a dietitian at work in a hospital. Suppose a doctor prescribes that each meal for a patient must have a minimum of 220 mg of vitamin C, 55 g of protein, and 800 calories. The dietitian must plan the meal observing the doctor's nutritional requirements. Problems of this sort can be very complicated and to solve them usually involves the use of algebra. To simplify this problem somewhat, suppose the meal is to be baked potatoes (one baked potatoe contains 100 calories, 5 g of protein, 20 mg of vitamin C), steak (3 oz. contains 300 calories, 20 g of protein, no vitamin C), and broccoli (150 g contains 50 calories, 5 g of protein, 100 mg of vitamin C). The dietitian's problem is to determine the number of servings of each food item which gives a meal balanced between meat and vegetables and which still meets the doctor's requirements.

Let s be the number of 3 oz. servings of steak, p be the number of baked potatoes, and b be the number of 150 g servings of broccoli. Then algebra helps the dietitian set up the equations which represent the number of servings of steak, baked potatoe and broccoli which meets the doctor's requirements:

$$300s + 100p + 50b = 800 \text{ calories}$$
$$20s + 5p + 5b = 55 \text{ g of protein}$$
$$20p + 100b = 220 \text{ mg of C.}$$



2 slices bread (64 cal./slice)
4 tbsp. peanut butter (100 cal./tbsp.)
2 tbsp. jelly (85 cal./tbsp.)
12 oz. milk (148 cal./8oz.)

HOW MANY CALORIES DOES THIS LUNCH CONTAIN?

Solving these equations for s, p, and b gives the dietitian the number of servings of steak, baked potato, and broccoli which meet the doctor's minimum nutritional requirements for the patient. Have you learned to solve simultaneous algebraic equations? If you have, solve these equations; if not, maybe you should take algebra.

Dietitians who work in hospitals must solve diet problems similar to our problem but for many different patients with many different nutritional diets. So they not only need to know mathematics but they also require training with the computer to help keep track of all the many diets and requirements.

Nutritional problems similar to our example are also faced by ANIMAL SCIENTISTS who specialize in the breeding and feeding of farm animals.

Agronomist

An AGRONOMIST is a food scientist who specializes in developing new methods of growing crops, obtaining higher crop yields, and improving crop quality. One of their greatest difficulties is to measure whether new developments actually result in crop improvements. What makes this such a difficult problem is the large number of variables which affect the growing of crops: soil quality, rainfall, insects, climate, fertilizer, weeds, and many others. Their methods of testing for improvements, consequently, involve the collecting of data and the use of mathematics and statistics to analyze this data. By means of statistical analysis they can often compare the hardiness and yield of one type of grain to another type grown in a previous year or in another location.

To become an agronomist it is necessary to attend a college which offers a program of study in agronomy. Such a program includes the study of soil chemistry, grain technology, plant breeding, crop cultivation, mathematics, and statistics.

GEORGE WASHINGTON CARVER
AGRONOMIST & AGRICULTURAL CHEMIST
1864-1943

Restaurant Manager

The RESTAURANT MANAGER is an individual who must coordinate the activities involved with serving a large number of meals each day. Work schedules, advertising, ordering, pricing, and customer relations are some of the activities which need to be coordinated.

Many of these are concerns which the manager of any business must face. Mathematics is helpful in these business matters. To see why just read pages 8 - 10. However, many other concerns are food related. For example, the problem of pricing meals and food items on the menu is a mathematical problem which, if it is not done skillfully, can result in the restaurant going out of business, even though the food and the service are excellent. If the prices are too low, the restaurant will operate at a loss and if the prices are too high, the number of customers may be few. This delicate problem of finding the right prices which generate profitable business is solved by combining business know-how and menu planning with mathematics.

for more information, write to:

- American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, Mich. 49085
- American Dietetic Assoc., 430 N. Michigan Ave., Chicago, Ill. 60611
- National Institute for the Foodservice Industry, 20 N. Wacker Dr., Suite 2620, Chicago, Ill. 60606

mathematics at work in FARMING

One device which a FARMER uses when planting a crop is a row-crop drill planter. It is a machine which is attached to the farmer's tractor to help the farmer plant seeds along a row so that the space between the seeds is always the same.

The drill planter has two mechanisms, which are used for adjusting the space between seeds planted in a row: a circular seed plate which has a fixed number of openings, called cells, for holding seeds, and a lever which adjusts the number of full turns of the circular seed plate for each complete turn of the drill planter's wheels.

The drill planter which our farmer has comes with four different circular seed plates: a plate with 6 cells, one with 9, one with 12, and one with 36 cells. Changing circular seed plates changes the seed spacing. Also, the space between seeds can be further adjusted by a lever which changes the number of turns of the seed plate from 1 to 4 turns for each complete turn of the drill planter's wheels. The lever is designed so that the farmer can choose a setting between 1 and 4 in steps of $\frac{1}{10}$ of a turn. To find the space between seeds in inches we use the formula

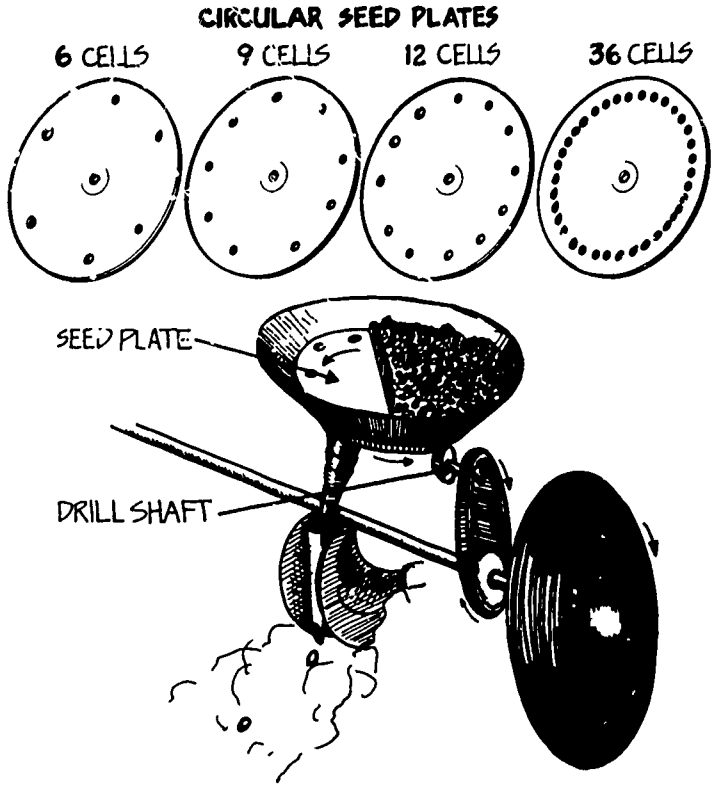
$$\text{SPACE} = \frac{\pi \times D}{C \times T}$$

where D is the diameter in inches of the drill planter's wheels, C is the number of cells in the seed plate, and T is the number to which the lever has been set (π approximately equals 3.14).

The wheel diameter on our drill planter is 36 in. If the farmer uses the 9-cell plate and sets the lever at 2.4 turns, then the seeds will be spaced about

$$\text{SPACE} = \frac{\pi \times 36}{9 \times 2.4} = 5.2 \text{ inches apart.}$$

1. What is the space between seeds if the 6-cell plate is used with the lever set at 1.2?
2. What are the different seed plates and settings which give a space of 2π inches between seeds?



3. To plant corn the farmer uses the 12-cell plate with the lever set at 3.1 turns. What is the space between seeds for corn?
4. To plant wheat the farmer uses the 36-cell plate with the lever set at 3.6 turns. What is the space between seeds for wheat?
5. The wheat seed spaced as in problem 4 is planted in rows 242 ft. long on a field 180 ft. wide. How many rows are planted if the rows are 8 inches apart? How many seeds are in each row? Finally, how many seeds are planted in this field, 180 ft. wide by 242 ft. long? (This field is one acre in area.)
6. The harvest of wheat kernels is about 40 times more than the number of seeds planted. How many kernels of wheat can be grown on one acre of land with the spacing of problem 5?
7. Express the yield of wheat found in problem 6 in bushels of wheat per acre. There are about 900,000 kernels of wheat in one bushel.

HEALTH

Caring for the health of people and animals is an important and rewarding career. It is a career which requires dedication and a strong sense of responsibility. And most health careers also require the study of mathematics. Why mathematics? One of the basic activities in serving the health needs of people and animals is taking measurements, for example, heart rate, blood pressure, blood count, and the amount of medicine to prescribe to name a few. Mathematics gives the training to perform these measurements accurately thereby preventing injury to a patient.

Veterinarian

Do you like animals? Animals need people to keep them healthy. This is the main job of doctors called VETERINARIANS. They diagnose, treat, and control diseases and injuries among animals. They usually work in their own private clinics, in hospitals, on farms, or on ranches.

All states require veterinarians to have a license to practice. To obtain a license it is necessary to attend 4 years of college, taking courses in mathematics, biology, and the natural sciences, followed by at least 2 years studying veterinary medicine in the classroom and in the clinic. The preparation for a veterinarian is very challenging and the mathematics which you take in high school, two years of algebra, geometry, and trigonometry, will help you to meet this challenge.

Perhaps, you like animals but you do not wish to spend 6 years in college to become a veterinarian. There are other careers for you to consider such as WILDLIFE CONSERVATION, ANIMAL WELFARE, and ANIMAL TECHNOLOGY.

An ANIMAL TECHNOLOGIST is trained to assist veterinarians in clinical practice, laboratory animal care, zoo medicine, and diagnostic work. The program of study for an animal technologist requires two years of college level study which includes mathematics, biology, clinical techniques, nutrition, and animal care.

Let's look at an example of mathematics working for the veterinarian and the animal technologist. A dog has an infection which can be treated by a liquid medicine with instructions: give 2 mg per pound per day. The dog weighs 36 pounds and one ml of the liquid contains 50 mg of medicine. How many ml should be given to the dog each day?

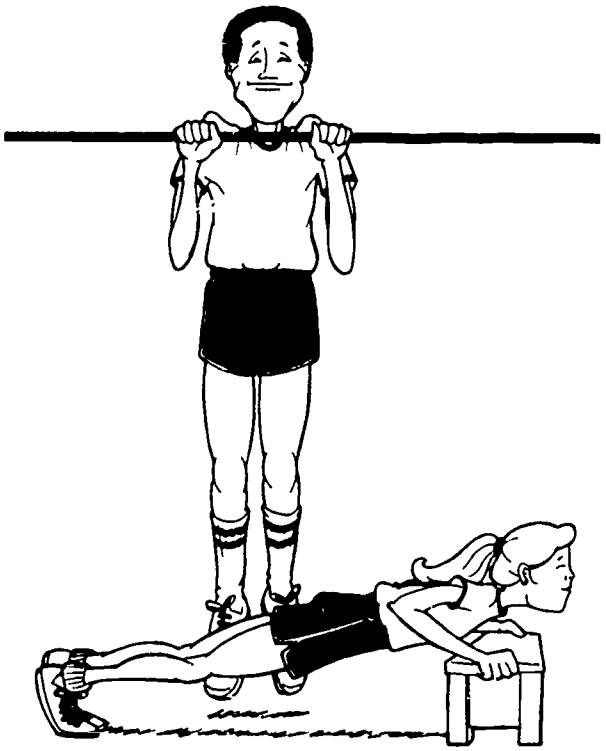
Physical Fitness Careers

Careers in physical fitness are careers which are devoted to helping people keep their bodies healthy and strong. These are important and rewarding careers. President John F. Kennedy once said "intelligence and skill can only function at the peak of the capacity when the body is healthy and strong." Some of the many careers in physical fitness are: PHYSICAL EDUCATION TEACHER, COACH, PARK/PLAYGROUND DIRECTOR, RECREATION DIRECTOR, and PHYSICAL THERAPIST.

PHYSICAL THERAPISTS help people to overcome physical disabilities received from disease or injury. They perform tests which measure motor development and muscle strength. Anyone who enters a career in physical fitness must learn various tests for measuring muscle strength. A simple formula for measuring arm strength is the following:

$$\text{ARM STRENGTH} = (C + P) \times \left(\frac{W}{10} + (H - 60)\right)$$

where C is the number of chin-ups you can do, P is the number of push-ups you can do, W is your weight in pounds, and H is your height in inches (if H is less than 60 inches, then put 0 in place of H - 60 in the formula). Compute your arm strength. If you arm wrestle with a classmate, the winner should be the one with the larger arm strength. Try it out! This is one example of measurement and mathematics at work in physical fitness.



Medical Careers

Whenever people think of medical careers they usually think of DOCTORS, NURSES, and DENTISTS. These important careers are the most visible careers in health care. But what are some other medical careers which are just as important? Here is a brief list.

PHYSICIAN'S ASSOCIATE: trained to assist a doctor in the general practice of medicine; a physician's associate may examine and diagnose patients under the doctor's supervision. Training: 2 years of college plus 2 years of specialized study in an associate's program.

DENTAL HYGIENIST: cleans and polishes teeth, provides counseling on proper dental care, and prepares dental histories, X-rays, and teeth impressions for the dentist. Training: 2 years of study in a junior or community college dental hygienist program.

OPTOMETRIST: examines eyes for vision problems and disease, prescribes lenses to correct vision problems, and when disease is discovered, refers patient to the appropriate physician. Training: 4 years of college plus 2 to 3 years of specialized study at an accredited college.

PHARMACIST: dispenses drugs and medicines prescribed by physicians and dentists. Training: 4 years of college plus 1 year of specialized training.

EMERGENCY MEDICAL TECHNICIAN: provides a patient with emergency first aid and transportation to a hospital; an "EMT" is sometimes called an ambulance attendant. Training: high school diploma plus an 81-hour course in emergency medical care usually offered by police, fire, and health department.

All of these careers require good technical training. If you are interested in one of these careers, begin to prepare now by taking mathematics in high school.

for more information, write to:

- American Veterinary Medical Association, 930 N. Meacham Rd., Schaumburg, IL. 60196.
- American Physical Therapy Assoc., 1156 15th St. N.W., Washington, D. C. 20005.
- American Hospital Association, 840 N. Lakeshore Dr., Chicago, IL 60611.
- American Medical Assoc., 535 N. Dearborn St., Chicago, IL 60610.

mathematics at work in HEALTH

PEDIATRICS is the branch of medicine which specializes in the health care of infants and children. An important question which doctors and nurses face when treating children is: how much medicine should the child be given? The answer is the least amount of drug which will produce the desired effect. This answer is not very helpful to a nurse or a doctor who is faced with prescribing medicine to children. They prefer an answer which gives a specific amount and mathematics provides the answer.

There are several mathematical formulas which are used by doctors and nurses to prescribe dosages to children. All compute the fraction of the standard adult dose for a medicine which can be given to a child.

For infants, children from birth to age 2, Fried's Rule

$$\text{INFANT DOSE} = \frac{\text{Age in Months}}{150} \times \text{ADULT DOSE}$$

is used. For children between the ages of 2 and 12 there are two rules. One is Young's Rule, based on the child's age:

$$\text{CHILD DOSE} = \frac{\text{Age(Yrs.)}}{\text{Age(Yrs.)} + 12} \times \text{ADULT DOSE.}$$

The other is Clark's Rule, based on the child's weight:

$$\text{CHILD DOSE} = \frac{\text{Wt. in pounds}}{150} \times \text{ADULT DOSE.}$$

1. The adult dose of a drug is 200 mg. How many milligrams of this drug does Fried's Rule recommend for a 6 month old infant?

2. The average weight of two year old children is 27 pounds. Find the recommended dose for such a child using all three rules, if the adult dose is 500 mg.

Problem 2 indicates the trouble with these rules for prescribing medicine for children. They do not agree! The fact is that people of the same age are not all the same size. Looking at your class- will easily prove this.

To account for the difference in sizes in the problem of prescribing the correct dose of medicine for children, doctors and nurses rely on mathematics to express the child's size in terms of the surface area of the child's body. A formula which approximates the body surface area is

$$\text{Area} = .08W + .13H - 1.03$$

where W is the child's weight in pounds, H is the child's height in inches, and Area is expressed in square feet. Since the average adult surface is 18.3 square feet, we can compute the correct child's dose as follows:

$$\text{CHILD DOSE} = \frac{\text{Area}}{18.3} \times \text{ADULT DOSE.}$$

3. The average two-year old weighs 27 pounds and is 33 inches tall. Find this child's body surface area and the recommended dose for this child given by the Area rule, if the adult dose is 500 mg.

4. Compute the body surface area from the given formula for each member of your family.

5. What fraction of the adult dose of medicine should your doctor prescribe for you?

SCIENCE and TECHNOLOGY

Mathematics is a science and it is also the language which other scientists use to communicate theories and to take measurements. It should come as no surprise, then, to learn that a career in science, whichever branch it may be, requires solid training in mathematics.

Life Scientist

Life science is the study of living organisms and the relationship of plants and animals to their surroundings. Those who work in this area are called life scientists. They can be BIOLOGISTS, BOTANISTS (plant specialists), AGRONOMISTS (see page 18), ZOOLOGISTS (animal life specialists), or ECOLOGISTS (environment specialists).

Much of their work involves measurement and estimation. To perform these tasks they need mathematics. ICHTHYOLOGISTS, fish specialists, use mathematics when they need to estimate the number of ish in a pond. The thought of catching all the fish and counting the catch is not realistic. Mathematics, especially probability, provides them with a method of solving this problem.

On the first day, a net is placed in the pond. Suppose 48 fish are caught. These fish are marked and thrown back into the pond. On the second day, the net is again placed in the pond. This time 156 fis. are caught and inspection shows 6 of them are fish which were marked the previous day. The chance of catching a marked fish in the pond is the fraction 48/n where n is the total number of fish. The fraction of marked fish to the total catch of the second day is 6/156. If we assume that fish are likely to swim in an unpredictable way, then the two fractions should be equal:

$$\frac{48}{n} = \frac{6}{156}.$$

Help the ichthyologist by solving for n, stimated number of fish in the pond.

Technical Secretary

Progress in science is accomplished by the free flow of ideas from one scientist to another. Written reports, books, and articles are still the best means of exchanging ideas between scientists and engineers. But who is qualified in secretarial skills and is able to correctly type mathematical formulas such as

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

from handwritten papers? Men and women TECHNICAL SECRETARIES! That's who!

Technical secretaries need a strong high school math program in addition to the usual secretarial courses like typing and shorthand. The mathematics, such as algebra and trigonometry, give them enough background to sense the proper way to type even very advanced mathematical formulas. With the recent development of word processors (computerized typewriters with a TV monitor), all secretaries should have some training with computers.

Chemist

Whenever iron reacts with oxygen, the result is rust. the familiar reddish brown substance. The CHEMIST uses algebra to represent this chemical process by the following balanced chemical equation

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3.$$

Here Fe denotes one atom of iron, O_2 denotes two atoms of oxygen, and Fe_2O_3 denotes iron oxide or rust, each molecule composed of 2 iron atoms and 3 oxygen atoms.

Chemical experiments show that 223.2 grams of iron yield 319.2 grams of rust in the reaction

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3.$$

If you come across a piece of rusty iron, scrape off the rust and weigh it. Suppose it weighs 48 grams. How much iron has been converted to rust? Use your mathematics, especially proportions, to solve this chemistry problem.

Chemists have developed many products which we use today: plastic, medicine, fertilizer, perfume, synthetic rubber, polyester fabric, and nylon to name a few. Look around your home or school for examples of chemistry at work for you.

The training to be a chemist requires at least 4 years of college, taking chemistry courses, such as analytic, inorganic, organic, physical, and biochemistry. To prepare for a career as a chemist it makes good sense to take chemistry in high school along with, yes, you guessed it, two years of algebra, one year of geometry and one year of trigonometry. You will need your algebra to balance chemical equations. You will need high school mathematics to prepare you for the college mathematics required for the chemistry program.

An important problem for a laboratory chemist is the problem of mixing and diluting chemicals to exact requirements. For example, suppose a beaker contains 2 liters of a solution which is 20% $C_{12}H_{22}O_{11}$ (the chemical name for sugar) and 80% water. Because the concentration of $C_{12}H_{22}O_{11}$ is too strong, the chemist wishes to pour off an amount of the solution and replace the amount poured off with water to obtain 2 liters of a weaker 5% $C_{12}H_{22}O_{11}$ and 95% water solution. How many liters of the 20% $C_{12}H_{22}O_{11}$ solution should be poured off and replaced by water to obtain the 5% $C_{12}H_{22}O_{11}$ solution? Call this amount w. The algebraic equation

$$0.8 \times (2 - w) + w = 0.95 \times 2$$

represents the chemist's problem. Can you see why? Solve the equation for w.

for more information, write to:

- Mathematical Assoc. of America, 1529 18th St., N.W., Washington, D. C. 20036
- American Chemical Society, 1155 16th St., N.W., Washington, D. C. 20036
- American Institute of Biological Sciences, 1401 Wilson Boulevard, Arlington, VA 22209
- National Secretaries Assoc., 2440 Pershing Rd., Suite G10, Kansas City, MO 64108

mathematics at work in SCIENCE and TECHNOLOGY

Imagine how complicated the mathematics is for sending a space shuttle safely into orbit or to the moon. To solve this problem many scientists and mathematicians, working together as a team, must describe the pull of the earth's gravity on the shuttle mathematically.

If we look at a simpler situation, the effect of gravity on objects hurled straight up or dropped, mathematics very nicely describes the motion of these objects as gravity pulls them. To keep the equations as simple as possible, the effect of air resistance is ignored.

First, let's look at some equations for objects which are dropped from a height. The basic equations are

$$D = 16 \times T^2 \text{ and } V = 32 \times T$$

where D is the length in feet of the object's fall after it is dropped, T is the time in seconds it takes for the object to fall, and V is the velocity or speed of the object as it strikes the ground; V is expressed in feet per second.

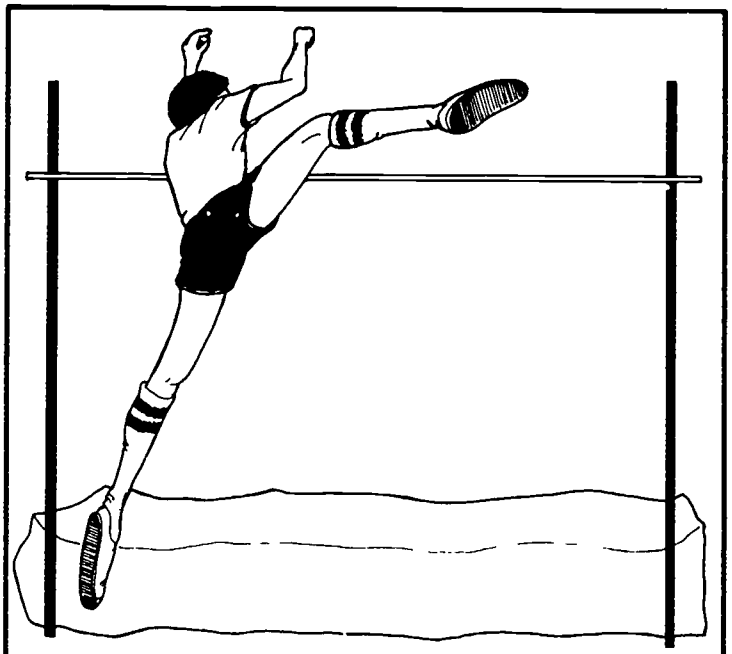
1. Suppose we drop a rock into a well and, with a stopwatch, we hear the sound of the rock hitting the bottom 2 seconds after it is dropped. How deep is the well?

2. A baseball player once caught a ball which was dropped from an airship from a height of 1000 ft. How many seconds did it take to drop? How fast was it going when it was caught? Use 44 ft./sec. = 30 miles/hr. to give the answer in miles/hr.

Now, let's look at some equations which give information about objects hurled straight up. The equations are

$$H = 4 \times T^2 \text{ and } V = 16 \times T$$

where H is how many feet above ground level the object goes, T is the number of seconds it takes the object to go up and come down, and V is the speed in feet/second at which the object is hurled.



Suppose you jump straight up with a speed of 22 ft./sec. (15 miles/hour). How high will you go? Is this a world record?

3. Suppose a ball is thrown straight up with a speed of 132 ft./sec. (90 miles/hr.). Some baseball players can throw this hard. How many seconds does the ball travel in the air? How high does it go (use 10 ft. = 1 story to express the answer in stories of a building)?

4. Using these equations and a stopwatch you can measure how high and how fast you can throw a ball straight up. Try it!

Wouldn't it be great to take a trip to the moon to see how high we can throw a ball there? Science and mathematics make it possible. Equations for objects thrown straight up on the moon are

$$H = 0.6625 \times T^2 \text{ and } V = 2.65 \times T.$$

5. If a ball was thrown straight up on the moon with the speed in problem 3, how long in seconds and how high in feet would it go?

6. Use the speed which you found in problem 4 to find out how high you can throw a ball on the moon.

TRANSPORTATION

Transportation is the moving of people and goods from one place to another. When your grandparents were your age the reality of jet airplanes, high speed trains, and super oil tankers would have been taken to be pure science-fiction. They are real means of transportation today and it took science, engineering and mathematics to develop them. To keep airplanes, trains, and ships running people are needed to operate them (pilots and navigators) and others are needed to repair them. What lies in the future in transportation: the space shuttle? Whatever it is, mathematics will play a part in it.

Mechanic

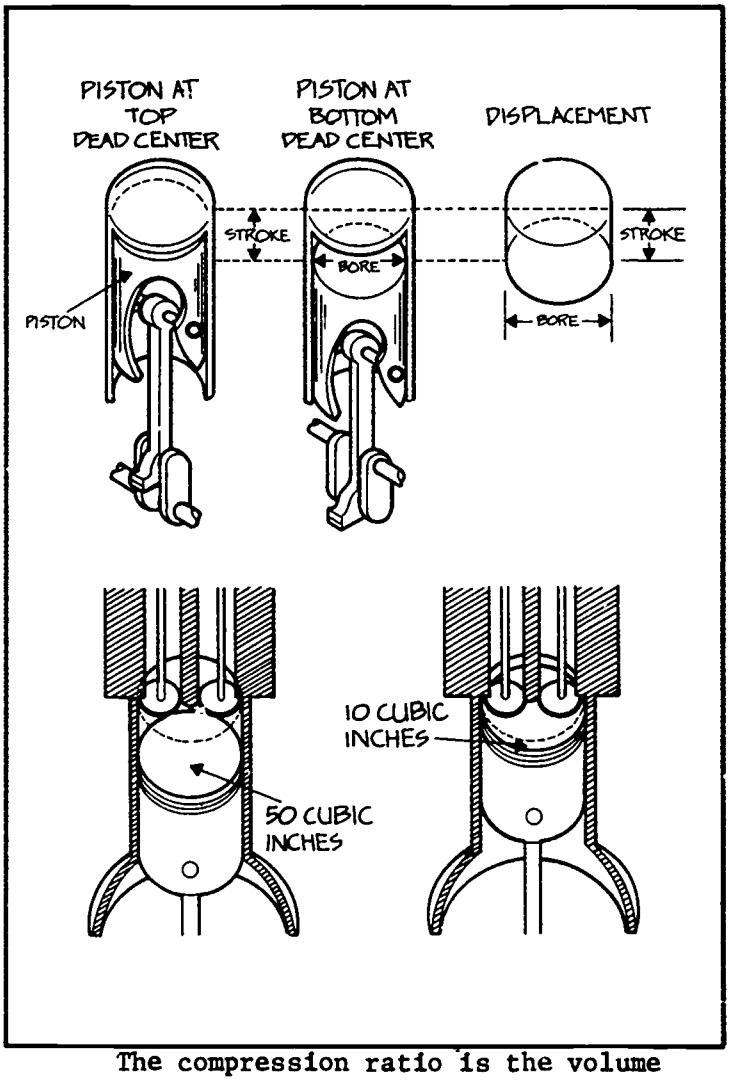
The MECHANIC is an important person when it comes to transportation. Mechanics are needed to keep our cars, buses, trucks, airplanes, and boats running. Good mechanics take pride in the ability to locate quickly the source of a problem and then to fix it; they must have good reasoning ability and a thorough knowledge of engines, power, and electricity.

Mechanics, especially racing mechanics, must use mathematics for designing engine specifications which increase the engine's power and efficiency. Their work is filled with terms such as engine displacement, compression ratio, bore, and stroke to name a few.

A piston is a metal cylinder which can move up and down in a chamber. A mixture of fuel and air blown into the chamber is compressed and ignited by a spark when the piston is upward. The resulting explosion drives the piston downward. When several pistons, 4, 6, or 8, are placed in staggered fashion in an engine, the combination of ignitions causes the up and down motion of the pistons to turn a shaft, and this propels a car. The diameter of the piston chamber is called the bore, B; the length of the up and down movement of the piston is called the stroke, S. The piston displacement, P, is the cylindrical volume which the piston head sweeps out as it moves from one end of its stroke to the other. It is given by

$$P = \frac{\pi \times B^2 \times S}{4}$$

(π approximately equals 3.14). The engine displacement is the piston displacement times the number of cylinders in the engine.



The compression ratio is the volume in the chamber above the piston when the piston is at the bottom of its stroke divided by the volume in the chamber above the piston when the piston is at the top of its stroke.

Suppose a 6-cyclinder car has a bore of 4 inches, a stroke of 3.25 inches, and a compression ratio of 10. Find the piston displacement, engine displacement, and total volume of the piston chamber. Borrow someone's auto owner's manual; look up the engine specifications and use the above formulas with them.

Truck Driver

There are two kinds of TRUCK DRIVERS, local and long-distance haulers. They may use a company truck or own their own truck. Whichever the case, truck drivers use mathematics in their work.

Local drivers usually work an eight-hour day and make many different stops delivering and receiving goods. This involves keeping careful accounting records of deliveries and receipts and that means using math skills.

Long distance haulers usually drive for 10 hour stretches (maximum allowed by law) followed by at least an 8-hour break. If they own the truck, they have as many concerns as a person who owns a business, keeping track of expenses such as gasoline costs, highway tolls, meals, overall truck wear-and-tear, and taxes; mathematics is useful in keeping tabs on a business.

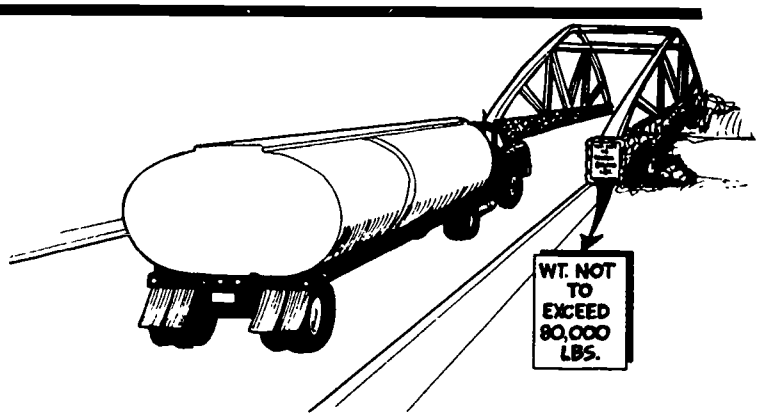
Two examples of mathematics working for a truck driver are computing gas mileage and estimating the truck's payload weight (the weight of the empty truck plus the weight of its load).

For gas mileage, use

$$\text{GAS MILEAGE} = (M_2 - M_1) \div G_2$$

where M_1 is the vehicle's mileage at the first gas fill-up, M_2 is the vehicle's mileage at the second gas fill-up, and G_2 is the amount of gas in gallons at the second fill-up. The formula gives the number of miles traveled per gallon. Try it out, with Mom or Dad's help, on the family car!

Often a truck driver must cross bridges with posted weight limits. Before setting out on a haul, the driver sometimes must compute the payload weight. One example is the driver of a gasoline truck. The empty truck weighs 20,000 pounds. Loaded it contains 10,000 gallons



of gasoline and gasoline weighs 0.8 as much as water (a number which expresses the number of times more than the weight of water a substance weighs is called the specific gravity of a substance; the specific gravity of gasoline is 0.8); water weighs 8.33 pounds per gallon. Is it safe for the driver to cross a bridge, with this loaded truck, if the bridge has a load limit of 80,000 pounds?

Truck drivers must have a good driving record and some automotive mechanic skills which are handy for minor roadside repairs.

Travel Agent

It was once a policy that TRAVEL AGENTS were hired only if they knew their world geography, especially through their own first-hand experiences.

Today, however, a travel agent must combine a knowledge of geography with training with computers. Most travel shops have computer terminals which communicate directly and instantly with bookings and ticket information of all major travel carriers whether they serve by air, land, or sea. Many times each day the travel agent will be asked to create an exciting family vacation or to plan a routine business trip by computer, searching for the lowest fares and the most comfortable routes. To solve these travel requests by computer can demand all the skill and resourcefulness one has learned from high school mathematics.

for more information, write to:

- American Trucking Assoc., Inc., 1616 P St., N. W., Washington, D. C. 20036
- Automotive Service Industry Assoc., 444 N. Michigan Ave., Chicago, Ill. 60611

mathematics at work in TRANSPORTATION

The job of a TRAFFIC CONTROL ENGINEER involves monitoring traffic conditions, determining speed limits, the placement of stop signs and traffic signals as well as timing traffic signals to permit the best flow of cars and trucks.

Let's help the traffic control engineer time the traffic signals along a stretch of Main Street. Traveling from west to east along Main St. the cross streets are called First St., Second St., and so on. Each block is 660 ft. long (1/8 mile). There are traffic signals at First, Fourth, Thirteenth, Eighteenth and Twenty-fifth St. going east on Main. Each traffic signal completes its cycle from green (30 seconds) to amber (3 seconds) to red (27 seconds) in 60 seconds. The speed limit on Main St. is 30 miles per hour (44 feet per second).

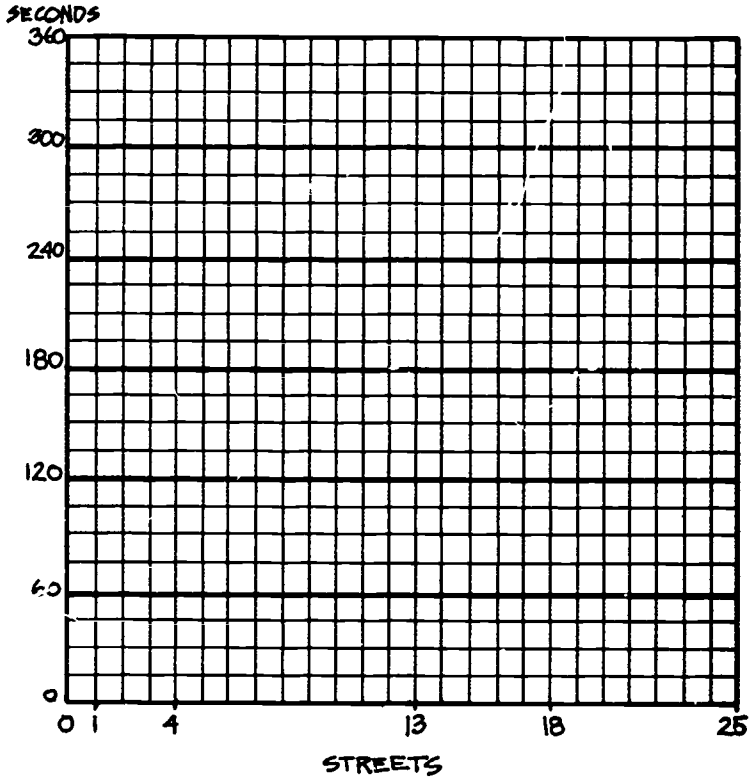
Here is the traffic control engineer's problem: how should the traffic signals be timed with respect to each other to permit a car traveling at a constant speed of 30 miles/hour to pass through each (green) signal at the same time of the cycle. Two reasons for setting the signals like this are it permits a better flow of traffic and it encourages drivers to obey the posted speed limit.

To solve this problem, begin by assuming that a car travels at a constant speed of 30 miles/hour traveling east on Main passing the intersection of Main and 1st at time 0 seconds (a stopwatch is being used).

1. Use the formula D = R × T, that is, DISTANCE = RATE OF SPEED × TIME to find the time in seconds when the car crosses 4th, 13th, 18th, and 25th (1 mile = 5280 feet).

2. Plot the points (street, time) on the coordinate system given on this page and connect these points by a straight line (one point is (1,0)).

3. From the graph find the time (in seconds) it takes for the car to travel on Main from 7th to 25th.



4. To time the traffic signals, the light at Main and 1st is set and then the others must be set with respect to the first light. If the car reaches 1st just as the signal turns green, how should the signal at 4th be set so that it will turn green just as the car reaches 4th St. Give the answer by stating how many seconds into its 60 second cycle the signal at 4th must be the moment at which the signal at 1st starts its cycle. The graph of exercise 2 is helpful. How should the other signals be set?

5. Suppose another car travels west on Main at 30 miles/hour with the signals timed as in problem 4. Assume this car passes 25th just as the signal turns green at time 0 seconds. Do exercise 1 and 2 for this car; use the graph on this page (one point is (25,0)).

6. Will the car of exercise 5 be stopped by any red lights? Where?

7. Solve the problem of timing the signals for east-to-west travel on Main St.

STATISTICS

Statistics is the mathematical science of collecting and analyzing numerical data. The systems analyst (page 8), the geologist (page 14), the ichthyologist (page 23), and the traffic control engineer (page 28) are examples of professionals in this book which illustrate the importance of statistics as a tool. But statistics can be used in all careers to help answer specific questions. For example, the interior designer observes cooks at work and counts how many times each appliance is used to determine the best time-saving layout for a kitchen. Before selling a new product, say a new soft drink, a company will ask a few people to compare the new soft drink to other brands. From the responses they decide how to advertise the soft drink- it tastes great; it refreshes; or it's less filling.

In these examples a sample of information is used. Only the actions of a few cooks are studied. The opinions of a few are used to guess how others may react to the new soft drink. Statistics helps to predict the probable answer to questions from a sample of information when it is impossible to get all the information needed to answer the question exactly. If you would like a career in statistics, begin with 4 years of high school math, including geometry, trigonometry, and two years of algebra.

To predict answers to questions, it is not surprising that statistics uses probability, a branch of mathematics which developed from the study of gambling. Probability assigns a fraction to each possible outcome which can occur in an experiment or a study. For example, if a fair coin is tossed, probability states that heads will occur 1/2 of the time and tails will occur 1/2 of the time. If extra weight is added to the head side of the coin, then tails would occur more frequently and the coin would not be "fair". How could you determine the probability of heads for such a coin?

Guessing answers in an exam is a good example of probability and statistics at work. As a class project, take the exam on this page. The questions are deliberately chosen so that you will have to guess an answer from among 3 seemingly equal choices for each question. Thus the probability of guessing the correct answer for each question is 1/3. The probability of guessing all four answers is 1/81. The probability of getting only 1 answer wrong is 8/81. The probability of 2 wrong is 24/81. The probability of 3 wrong is 32/81. The probability of a zero score is 16/81.

1. Have the class take the exam and grade it. The answers are on page 32 of this book.
2. Calculate the percentage of the class that got 4 questions correct, 3 correct, etc. and compare these results with the predicted probabilities.
3. Compute the class's average score. How close does it come to the predicted average score of 4/3 correct?
4. Which exam question had the highest number of correct answers and which the lowest? Compare the percent of correct answers to each question with probability's predicted 1/3 of the class.

exam

1. The first woman graduate from an American medical school was
   a. Amelia Goodlow b. Alice Turner c. Elizabeth Blackwell
2. Russia's Minister of Finance from 1981 to 1903 was
   a. S. Y. Witte b. V. A. Zhukovsky c. N. M. Shvernik
3. Baseball's American League rookie of the year in 1952 was
   a. Jim Galvin b. Harry Byrd c. William Allison
4. Lake Michigan has a surface area in square kilometers of
   a. 58016 b. 69485 c. 62893

for more information, write to:

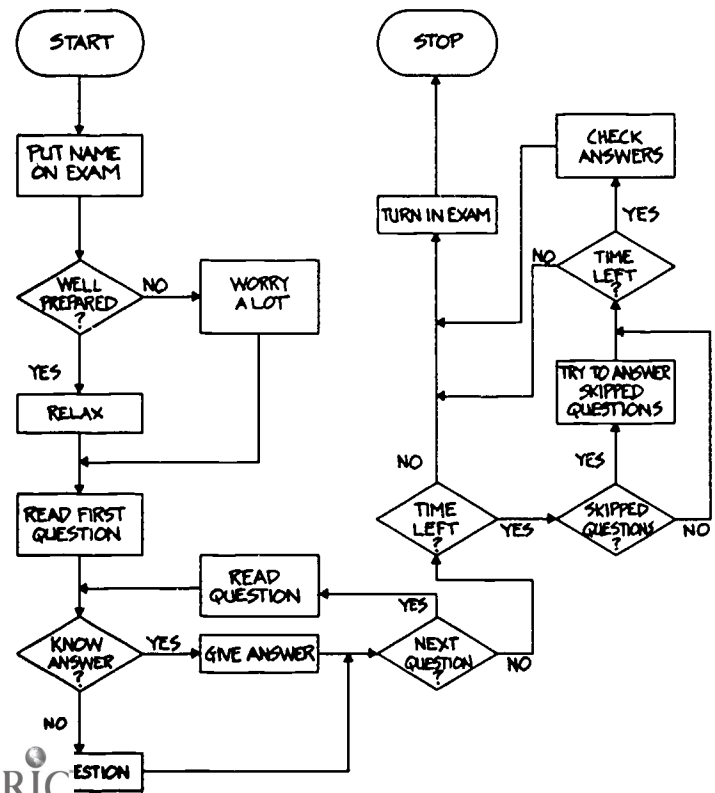
American Statistical Assoc., 806 15th St., N. W., Washington, D. C. 20005

COMPUTER SCIENCE

A computer is an electronic machine which is capable of high-speed calculations and of storing large amounts of information for later use. The computer, however, does not run itself. It needs to be guided in a step-by-step fashion by a set of instructions called a program. The people who create programs for computers are called computer programmers. The computer is an important tool in many of the professions described in this book. It is largely responsible for the increase in the number of highly technological careers nowadays. Practically all billing, accounting, and banking is handled by computer. The space program, the search for energy, the accumulation and tabulation of data in science and statistics, all of these need the computer. If the computer is a tool in the career of your choice, be prepared for it in advance by taking mathematics and computer science training in school. Such training will give you the edge in the competition for employment.

Most of you may not have had the chance to program a computer. Would you like to see what it's like to program a computer, and, also, to see the usefulness and the limitations of a computer while having a little classroom fun? Of course you would! First read what a flowchart is and, next, try the computer programming activity given on this page with a classmate.

A flowchart is a method which programmers use to diagram the solution of a problem. It helps them when they write a computer program. To write a flowchart, special boxes are used, connected by arrows, to show the start, the steps, the decisions, and the end of a flowchart. Below is a flowchart for taking an exam.



Try this computer programming activity with a classmate.

1. Write a flowchart which describes the step-by-step strategy which you use when you play "Tic-tac-toe", the game of X's and O's played on a nine-square grid where three in a row wins. Set a 15 minute time limit for making the flowchart. This should give you some practice as a programmer.
2. Exchange flowcharts with a classmate.
3. The flowchart which you have received in step 2 is your "program" for playing the game "Tic-tac-toe". You must pretend to be a computer and make the moves for the game exactly as described by this flowchart. Remember, the computer does only what it is told; if the program is written poorly, the computer will play poorly.

   Important: any dispute over the way in which a flowchart is followed must be settled by an impartial observer called a referee or teacher.
4. A game can end with either side making three-in-a-row, or it can end in a draw. Award 2 points to the flowchart that wins the game, 1 point to each flowchart in a draw, and 0 points to the flowchart which loses a game.
5. Play a 5-game series with a classmate. The person who wrote the flowchart with the highest point total is declared the winner.
6. Determine a class champion.
7. How would you improve your flowchart if given a second chance?

a final word about MATHEMATICS

Take mathematics in high school and be ready for the future. The more mathematics you take, the better prepared you will be:

- better prepared for a future as a consumer and citizen (see page 9),
- better prepared for a future as a problem-solver and decision-maker,
- better prepared for specialized career training whether it takes place at the college level, junior college level, vocational school level, or in an apprentice program for a skilled trade (see page 11),
- better prepared for keeping a job which may change with the rapidly improving technology.

These are some of the reasons why you should take algebra, plane geometry, and trigonometry in high school.

What if you avoid math in high school? What, you may ask, is the risk?

Well, your career choices will be greatly reduced and so will your future earning power (see page 3) and, consequently, your overall quality of living. Furthermore, by the time you finally realize the value of algebra, geometry, and trigonometry, you will be older with more personal responsibilities. When the older student returns to school, it is more difficult to pick up the mathematics which has been avoided. After being away from mathematics it is natural to have forgotten basic mathematical skills that right now are fresh in your mind. This is one obstacle which a returning older student must overcome.

The best time to take mathematics is while you are in high school.

Some of you, who are convinced of the importance of taking mathematics, are nevertheless, still reluctant, almost afraid, to take mathematics.

There is nothing unusual about feeling this way. Many students do. Mathematics courses demand a commitment to work at them seriously everyday. The easy way out for most students is to avoid math. High school teachers and counselors are familiar with the problems which make students reluctant to take mathematics. Talk to them about your interest in taking math and your wariness about actually doing it. Teachers are there to help students; the greatest joy a teacher can experience comes from helping, advising, and working with students who <u>really</u> want to learn and are <u>willing</u> to work to learn. You are such a student, aren't you?

Keep in mind that mathematics requires no special talents. Mathematics is a set of skills which can be learned, practiced, and developed by anyone willing to do the work. Many students, just like you, have shown this to be true.

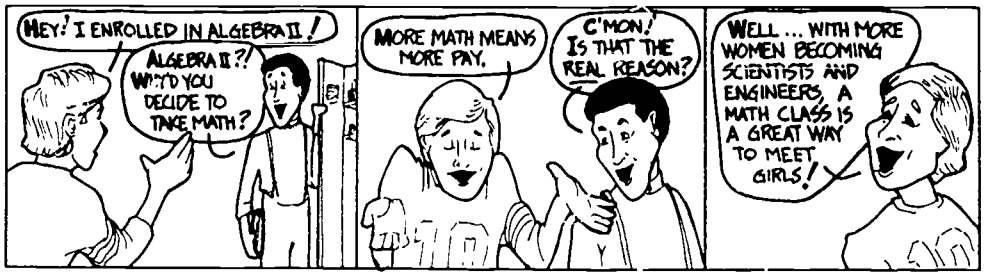
Math may be challenging, but life will be more difficult without it.

a final word about CAREERS

There are many more professions for you to consider as potential careers which were not included in this brief book Opening Career Doors. If you would like to find information about other careers: type of work done, starting salary, prospects for employment and advancement, and training required, then the reference to use is Occupational Outlook Handbook by the U. S. Department of Labor, Bureau of Labor Statistics. This book can be obtained through the school or municipal librarian or your school counselor. If you have the opportunity to browse through the Occupational Outlook Handbook, make a list of all the careers that actually mention mathematics as a part of the required training for that career. Your list will be quite long.

To obtain additional career information, interview or question adults about their careers. Ask questions such as: what training is needed, how good is the starting pay, what is the future outlook for their profession, how do they use mathematics in their jobs, and other questions of your own. You will be surprised to find how pleased adults will be to describe their job to someone who has expressed an interest in it.

Try this method out on a teacher or counselor in your school by asking them about their careers.



Where else should you look for career ideas? The best place is to look within yourself. What are your interests, what are your special talents, and what are your shortcomings? Try your best to know the answers to these questions. Then be creative about your possible future careers.

Do you enjoy studying art but you do not have any artistic skills such as drawing or painting? Then perhaps an art supply business or an art gallery is a possible career.

Girls! Do not overlook the area of science, engineering, and technology. More women are successfully accepting the challenge in this area but many more are needed.

Boys! If medicine and medical care is appealing to you but medical school is not, consider nursing. Today, more men and women are breaking down the artificial barriers of society to perform jobs which are fulfilling.

Do you wish a career in technology which requires very specialized and expensive training that you are unable to afford? Consider the U. S. Military Services as an option. They provide training and experience in a multitude of technological careers while you serve your country.

These are just some examples of creative career options.

Remember: you can be whatever you are willing to work hard to be. To prepare yourself for the future, take math, but also do your best to learn all that you can from all your high school courses. The opportunities are there for those who are prepared.

Answers for the exam on page 29 are 1c, 2a, 3b, 4a.

For more information on mathematics and your career, write to:

The Mathematical Association of America
1529 Eighteenth Street, N.W., Washington, D C. 20036